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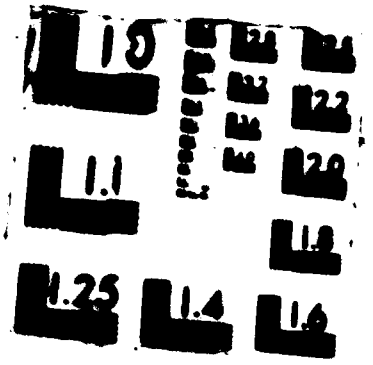
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This project concerned research on developing fast algorithms for implementation on a parallel processing system. Titles of research papers resulting from this effort include the following: Least squares methods for fourth order problems, Least squares methods for problems with corner singularities, Finite element methods for the streamfunction-vorticity equations, and On substructuring algorithms and solution techniques for the numerical solution of partial differential equations.

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Final Report for Air Force Office of Scientific Research Grant AFOSR 85-0277 Fast Algorithms for the CMU Attached Processor System

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We report on work performed with support of Air Force Office of Scientific Research Grant AFOSR 85-0277. We begin by listing the personnel which received some support from the grant:

George Fix - Professor of Mathematics;
Max Gunzburger - Professor of Mathematics;
R. A. Nicolaides - Professor of Mathematics;
William Layton - Visiting Associate Professor;
Bengi Guo - Post-doctorate Fellow; and
Maria Cayco - Post-doctorate Fellow.

We discuss research accomplishments by listing papers prepared under grant sponsorship and briefly describing their content. Preprints of these papers are being forwarded, under separate cover, to the contract monitor, Captain John Thomas.

Least squares methods for fourth order problems - G. Fix and E. Stephan - To appear in *Archive for Rational Mechanics* - The least squares finite element method has been shown to be useful for the approximate solution of second order elliptic partial

differential equations. In this work, the method is extended to fourth order elliptic problems. In particular, finite element algorithms are given which are optimally accurate and which do not suffer from the usual problems associated with the approximation of fourth order problems, e,g., do not require the use of high continuity finite element spaces

Least squares methods for problems with corner singularities - C. Cox and G. Fix - To appear in *Computers and Mathematics with Applications* - Typically, when the exact solution of boundary value problems for elliptic partial differential equations are singular due to the presence of corners in the boundary of the domain, least squares finite element methods do not achieve the same accuracy as do analagous methods applied to problems with smooth solutions. It is shown that through the use of appropriate weights in the least squares functional and appropriate mesh refinement techniques, that the optimal accuracy can be recovered. Such algorithms have been implemented in computer codes and extensive numerical experiments, as well as mathematical analyses have been carried out.

Finite element methods for the streamfunction-vorticity equations - G. Fix - To appear in the *Proceedings of the Conference on Numerical Methods for Water Resource Problems* - Existing theories for finite element methods for the streamfunction vorticity equations predict rates of convergence which are lower that those observed in practice. This includes the widely use case of methods which use continuous piecewise linear finite element spaces for both the streamfunction and vorticity. It is shown, through the use of novel mathematical techniques, that the finite element approximation of the derivatives of the streamfunction, and hence the velocity field, converges at an optimal rate. Improved error estimate for the vorticity approximation are also obtained.

On substructuring algorithms and solution techniques for the numerical solution of partial differential equations - M. Gunzburger and R. Nicolaides - To appear in *Applied Numerical Methods* - Substrucuring techniques, which contain large amounts of inherent parallelism, have long been popular methods of discretization and solution for positive definite problems in,

e.g., linear elasticity. We show how the method may be extended to indefinite, non-symmetric problems, even when the individual substructure problems are singular. Such cases arise in many applications. We discuss three of these, namely the Stokes equations of viscous incompressible flow, the Helmholtz equation of linear acoustics, and first order elliptic systems such as those which arise in problems involving potentials. Algorithms are discussed with special attention payed to issues connected with efficient implementations.

On central difference approximations to general second order elliptic equations - W. Layton - To appear in *Linear Algebra and its Applications* - Finite difference discretizations require a much stronger condition than ellipticity to yield a scheme of positive type. It is shown that the standard central difference discretization of general second order elliptic operators with periodic boundary condtitions is of monotone type, although it is not of positive type. Specifically, the inverse matrix arising from such a discretization has one sign.

A modified defect correction algorithm for the solution of singularly perturbed differential equations - V. Ervin and W. Layton - To appear in the *ACM Transactions on Mathematical Software* - A code is developed which implements a numerical method, devised and analyzed by the authors, for the approximate solution of singularly perturbed differential equations. The approach is to use a stable difference method to caculate a first approximation. This solution is then improved by estimating the associated errors using residues. Ordinary implementations of such methods result in improved accuracy away from boundary and interior layers, but causes such layers to spread to more grid points. This smearing effect is countermanded by a pre-processing procedure on the residues before caclculating an approximation for the associated error.

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